Slide 1

Administrivia

- For those of you thinking about graduate school — TWIST is sponsoring a panel discussion with Trinity alums currently in grad school, Monday at 6pm (I think — check fliers). We hope to have one CS alum.
- My Unix course is CSCI 3294-1, not CSCI 3290 as I said last time. FYI.

Slide 2

I/O Continued — Device Specifics

- Next, a tour of major classes of devices. For each, we look first at what the hardware can typically do, and then at what kinds of device-driver functionality we might want to provide.

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Clocks — Hardware

- System clock — can be simple or programmable. Programmable clock can generate either one interrupt after specified interval or periodic interrupts ("clock ticks").
- Backup clock — usually battery-powered, used at startup and perhaps periodically thereafter.

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Clocks — Software

- Clock(s) can be treated as I/O devices, with device driver(s). Functions to provide:
  - Maintain time of day.
  - Enforce time limits on processes.
  - Provide timer / alarm-clock function.
  - Do accounting, profiling, monitoring, etc.
  - Do anything required by page replacement algorithm (turn off R bits in page table entries, e.g.).
- Provide this functionality in code to be called on clock-tick interrupts.

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Character-Oriented Terminals — Hardware Overview

- Hardware consists of character-oriented display (fixed number of rows and columns) and keyboard, connected to CPU by serial line.
- Actual hardware no longer common (except in mainframe world), but emulated in software (e.g., Unix xterm) so old programs still work. (Why does anyone care? some of those old programs are still useful — e.g., text editors — and usually very stable.)

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Character-Oriented Terminals — Keyboard

- Hardware transmits individual ASCII characters.
- Device driver can pass them on one by one without processing, or can assemble them into lines and allow editing (erase, line kill, suspend, resume, etc.). Typically provide both modes.
- Device driver should also provide:
  - Buffering, so users can type ahead.
  - Optional echoing.

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Character-Oriented Terminals — Display

- Hardware accepts regular characters to display, plus escape sequences (move cursor, turn on/off reverse video, etc.).

  In olden days, escape sequences for different kinds of terminals were different — hence the need for a `termcap` database that allows calling programs to be less aware of device-specific details.

- Device driver should provide buffering.

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GUIs — Hardware Overview

- PC keyboard — sends very low-level detailed info (keys pressed/released); contrast with keyboard for character-oriented terminal.
- Mouse — sends (delta-x, delta-y, button status) events.
- Display can be vector graphics device (rare now, works in terms of lines, points, text) or raster graphics device (works in terms of pixels). Raster graphics device uses graphics adapter, which includes:
  - Video RAM, mapped to part of memory.
  - Video controller that translates contents of video RAM to display. Has two modes, text and bitmap.

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GUI Software — Basic Concepts

- "WIMP" — windows, icons, menus, pointing device.
- Can be implemented as integral part of o/s (Windows) or as separate user-space software (Unix).

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GUIs — Keyboard

- Hardware delivers very low-level info (individual key press/release actions).
- Device driver translates these to character codes, typically using configurable keymap.

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GUIs — Display (Windows Approach)

- Each window represented by an object, with methods to redraw it.
- Output to display performed by calls to GDI (graphics device interface) — mostly device-independent, vector-graphics oriented. A `.wmf` file (Windows `metafile`) represents a collection of calls to GDI procedures.

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Network Terminals — Hardware

- Keyboard, mouse, and display as described previously, plus local processor; connected to remote system.
- Local processor can be very capable (X terminal, or even PC configured to run as one) or more primitive (SLIM terminal).

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GUIs — Display (Unix Approach)

- X Window System designed to support both local input/output devices and network terminals, in terms of:
  - "X clients" are programs that want to do GUI I/O.
  - "X server" provides GUI services. Can run on the same system as clients, a different Unix system, an X terminal (where it's the "o/s"), or under another o/s ("X servers" for Windows — e.g., Exceed, XFree86).
- Core system is client/server communication protocol (input, display events akin to those in Windows) and windowing system. "Window manager" and/or "desktop environment" is separate, as are "widget" libraries. Modularity makes for flexibility and portability, at a cost in performance.

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GUI-Based Programming

- Input from keyboard and mouse captured by o/s and turned into messages to process owning appropriate window.
- Typical structure of GUI-based program is a loop to receive and dispatch these messages — "event-driven" style of programming.
- Details vary between Windows and X, but overall idea is similar. See example programs in textbook.

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Disks — Hardware

- Magnetic disks:
  - Cylinder/head/sector addressing may or may not reflect physical geometry — controller should handle this.
  - Controller may be able to manage multiple disks, perform overlapping seeks.
- RAID (Redundant Array of Inexpensive/Independent Disks):
  - Basic idea is to replace single disk and disk controller with "array" of disks and RAID controller.
  - Two possible payoffs — redundancy and performance (parallelism).
  - Six "levels" (configurations) defined.
- Optical disks — CD, CD-R, CD-RW, DVD. Okay to skim details!

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Disk Formatting

- Low-level formatting — each track filled with sectors (preamble, data, ECC bits).
- Higher-level formatting — master boot record, partitions (logical disks), partition table. Master boot record points to boot block in some partition. Partition table gives info about partitions (size, location, use).
- Partition formatting — boot block, blocks for file system (more about that in next chapter).

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Disk Arm Scheduling Algorithms

- A little more about hardware: Time to read a block from disk depends on seek time, rotational delay, and data transfer time. First two usually dominate.
- Earlier we said that typical device driver for disk maintains a queue of pending requests (one per disk, if controller is managing more than one). What order to process them in? several "disk arm scheduling algorithms":
  - FCFS.
  - SSF (shortest seek first).
  - Elevator.

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Disk Error Handling

- Almost all disks have sectors with defects. Some controllers can recognize them (repeated failures) and avoid them; if not, o/s (device driver) must do this.
- Other kinds of errors also possible, e.g., failure to correctly position read/write head; also must be handled either by controller (if possible) or o/s.

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Other I/O-Related Topics

- "Stable storage" — use two disks to provide what appears to be a single more reliable one (i.e., write either succeeds or leaves old data in place).
- Power management significant — some devices have "sleeping" and "hibernating" states, o/s can try to determine when it would make sense to use them. Example — screen blanking.

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Minute Essay

- Anything about I/O that's particularly unclear? that you want to hear more about? Tuesday I plan to talk a little about I/O in real systems and then go on to the next topic (filesystems).